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RIPPLE EAST, WORCESTERSHIRE: GEOARCHAEOLOGICAL DESK BASED ASSESSMENT

Prepared for Cotswold Archaeology Ltd

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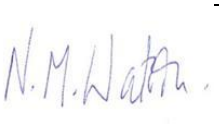
001	08/12/2022	E	Nick Watson		Keith Wilkinson	
*I – Internal draft; E – External draft; F – Final						

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SUMMARY

A geoarchaeological desk based assessment was undertaken on land at Ripple East, Worcestershire owned by CEMEX UK Operations Ltd. The work was commissioned by Cotswold Archaeology Ltd in November 2022 and involved the analysis of the logs of 20 geotechnical boreholes and relevant geological literature to investigate the potential for biological and Palaeolithic archaeological remains to be present on the fluvial terraces that cover the site. These terraces are assigned by the British Geological Survey (BGS) to the Holt Heath Sand and Gravel Member and the Worcester Member of the Severn Valley Formation and rest on bedrock of the Mercia Mudstone Group. The Holt Heath Sand and Gravel Member dates from MIS6 to MIS2 and has a complex record of deposition; the Worcester Member is more tightly constrained to MIS2 to MIS1 (Late Devensian); however, the deposits on or near the site have not been chronometrically dated.

The assessment revealed that the Holt Heath Sand and Gravel Member rests on a Mercia Mudstone Group bedrock bench at +14±1m OD; and that the Worcester Member lies between +7.65m OD in the south and +11.30m OD in the centre east of the main site also on the mudstone bedrock. The average thickness of the former is 2.4m (5 records) and of the latter 2.54m (12 records).

The potential for biological remains (in particular peat) and for in situ *Palaeolithic archaeological remains (in particular lithics) to be found in the terrace deposits is believed to be low. However, boreholes WOB7 and BH07/85 on the Worcester Member record fine grained and waterlogged clayey sand and the upper 1-2m of the Member is tentatively postulated as conducive to the recovery of peat or* in situ *artefacts. The drilling of purposeful geoarchaeological boreholes could significantly enhance the detail of any fine grained biological strata found and provide a means of dating via Optically Stimulated Luminescence.*

1. INTRODUCTION

1.1 This document reports on the results of a geoarchaeological desk based assessment undertaken on land at Ripple East, Worcestershire (henceforth 'the site'). The site is owned by CEMEX UK Operations Ltd and is part of an application to Worcestershire County Council (planning ref: 22/000015/CM) for the extraction of the sand and gravel mineral resource. The work was commissioned by Cotswold Archaeology Ltd to complement their Archaeological Evaluation (2022) and in order to fulfil conditions laid out by the County Archaeologist for Worcestershire County Council Emma Hancox The work has been carried out in accordance with Historic England's (2015) guidance on geoarchaeology.

1.2 The site is centred on NGR 387105 237415 just south of the village of Ripple and lies 3.3km southeast of Upton upon Severn, Worcestershire and 5.2km northwest of Tewksbury, Gloucestershire (Figure 1A and 1B). The main area of the site is approximately rectangular and occupies 0.14km^2 (Figure 1C). It is bound in the south by the M50 motorway, in the east by Bow Lane, in the north by agricultural land of the village of Ripple and in the west by a restoration lake of the former Ripple Quarry beside the River Severn. A narrow extension to the site lies south of the M50 on the east bank of the River Severn. The elevation of the site falls westwards from *c*.+12m OD in the east of the site to *c*.+9m OD in the west.

1.3 The British Geological Survey (BGS) (1988; 2022a) map the bedrock geology of the site as the Branscombe Mudstone Formation dating to the Late Triassic epoch 237 Ma – 201.3 Ma. The formation is a constituent of the Mercia Mudstone Group. The lithology of the bedrock is a reddish brown, structureless mudstone and siltstone that exhibits green reduction spots. Weathered bedrock displays a typically blocky habit and a silt/clay lithology (termed 'marl' in geotechnical logging on the site).

1.4 The BGS (2022a) also map two terraces of the River Severn overlying the Triassic bedrock on the site. The earliest and highest (outcropping at *c*.+17.5m OD) is the Holt Heath Sand and Gravel Member which occupies a slither of land along the eastern site boundary. On *c*.90% of the main area of the site lie the fluvial sands and gravels of the succeeding Worcester Member outcropping at *c*.+12m OD.

1.5 The BGS assign the Holt Heath Sand and Gravel Member to the 'Wolstonian' period[1] (marine isotope stage [MIS] 6). However, biostratigraphic and chronometric evidence point to at least three different (and later) depositional possibilities suggesting a protracted and complex depositional record (BGS 2022b). Briefly, the conundrum may be summarised as follows. First, deposits containing *Hippopotamus* (teeth) may lie at the base of gravels correlated to the Member at Stourbridge 45km to the north, implying a last interglacial date (MIS5e; 128 – 116ka[2]) given that that mammal is only known from Britain in the Ipswichian; however, cold faunal remains were also found that suggests reworking of older cold stage deposits almost definitely took place (Shaw 2021). Secondly, 29km north at Upton Warren like-named interstadial organic channel-fill sediments found within the Holt Heath Sand and Gravel Member are dated to mid MIS3 (*c*.42ka) by radiocarbon although this is at the end of the method's reliable range, and to, at least, early MIS3 by amino acid racemisation (Bowen *et al* 1989; Maddy 1999; Maddy and Lewis 2005). Finally, a Late Devensian Glacial (MIS2: 28.6 – 14ka) date is inferred by the presence of erratic clasts sourced from Scotland and the Lake

[1] The 'Wolstonian' is a period term no longer used in discussions of the British Pleistocene. It is equivalent to the north-west European Saalian, marine isotope stages 8–6 and the time interval 243,000–130,000 years ago

[2] ka = thousand years ago, i.e. 128,000–116,000 BP in the present instance.

District in the Member gravels within the Severn valley, and which are likely to have been transported by glaciers during the Last Glacial Maximum and then flushed into the Severn valley by melt water (BGS 2022b).

1.6 The Worcester Member was aggraded by the action of very high energy braided channels in a periglacial environment during a pause in the deglaciation of the Devensian ice sheet *c*.18ka (Maddy and Lewis 2005).[3] High energy flows on the ancient Severn braid plain resulted in the deposition of cross bedded sand beds and gravel beds composed of mainly Triassic quartzite pebbles and occasional exotics, the same as are found in the Holt Heath Sand and Gravel Member (BGS 2022b; Maddy and Lewis 2005). The Worcester Member forms, in fact, the penultimate fluvial terrace in the Severn Valley; the youngest and last is the Power House Member (its status is at present under review by the BGS) that lies below the Holocene alluvium on the valley floor. The latter is up to 12m thick and, in an exposure on the River Stour at Wilden, overlain by organic sediments dated from *c*.13ka to *c*.10ka (Shotten and Coope 1983). The Power House Member is not recorded in boreholes from the present site, however, but the 13–10ka ages from Wilden nevertheless provide a *terminus ante quem* for the aggradation of the Worcester Member. The time frame for the emplacement of the gravels of the Worcester Member coincides with the reoccupation of the British Isles by human groups. Humans are thought to have been absent from the UK during the cold of the Dimlington Stadial *c*. 26ka – the local expression of the global Last Glacial Maximum – and did not reappear until 14.7ka as the climate warmed into the Windermere Interstadial (Bølling/Allerød interstadial) (Pettitt and White 2012). It is therefore possible that *in situ* Late Upper Palaeolithic artefacts and organic material (peat) might be associated with any fine grained facies of the Worcester Member laid down in interstadial climates. It is notable in the latter regard that desk based study of boreholes in the vicinity of Bow Farm Quarry *c*.1km downstream, revealed rare Lateglacial peat lenses believed to be associated with the Worcester Member (Howard 2019,7).

1.7 The latest and final deposit mapped at Ripple East is Holocene Alluvium that occupies the western border of the main area of the site and the western extension on the bank of the River Severn (Figure 1C). The deposit is unconsolidated and consists of fluvial clay, silt, sand and gravel laid down at the end of the Pleistocene[4] and the beginning of the Holocene[5]. Peat beds may be intercalated in the alluvium.

1.8 The aims of the present geoarchaeological study were set out by County Archaeologist for Worcestershire County Council Emma Hancox (see Section 1.1 above), and include associated research priorities and questions as laid out in *Palaeolithic research in Worcestershire: Future Work and Research Priorities* by Hedge and Hancox (2021). The aims are therefore to:

1.8.1 Assess the superficial geology (with particular reference to the Worcester Member) of the Ripple East site with respect to quantifying the potential for the preservation of Pleistocene biological and Palaeolithic archaeological remains.

1.8.2 Determine whether investigation of the Worcester Member could assist in answering research question 14 of *Palaeolithic research in Worcestershire:*

[3] The stratotype of the Worcester Member is Grimley, OS grid reference 383218 261333 where a 10m thickness of gravels are present. (Dawson, 1989). The Member was known as the Worcester Terrace formerly the Second Terrace of the Severn (Wills 1938).

[4] The Pleistocene is the penultimate geological epoch dating from 2.6 Ma (million years ago) to 11.7 ka.

[5] The present geological epoch dating from 11.7 ka to the present day.

Future Work and Research Priorities, namely what date do we have for the re-occupation of the area after the Late Glacial Maximum?

1.9 The remaining sections of this report first set out the methodology by which the geoarchaeological desk-based study was carried out. The strata present on the site are then described, while the Assessment section considers the archaeological and palaeoenvironmental potential of the strata. Collectively this latter text addresses both the Aims.

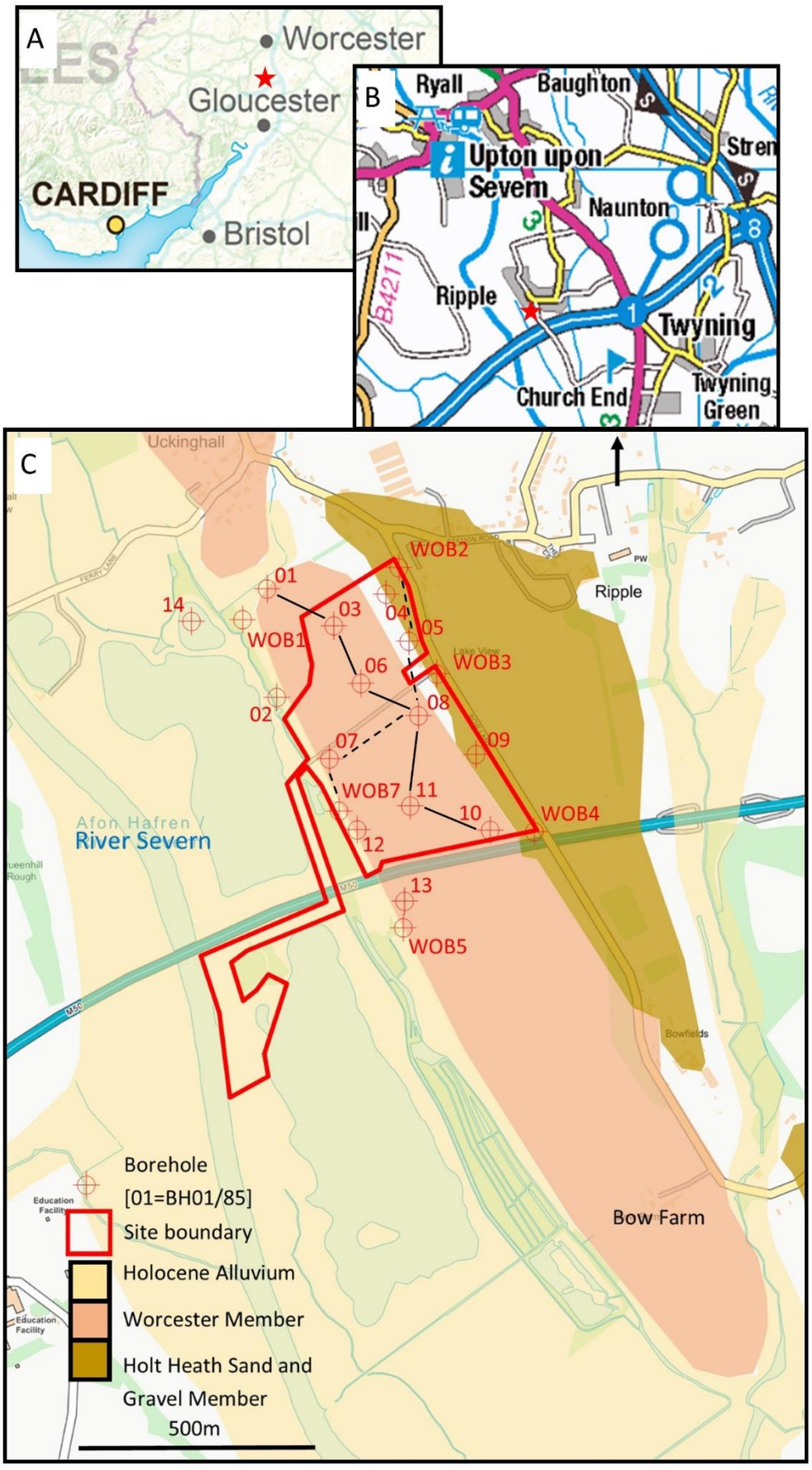

Figure 1. Location of the site (red star) within (A) southern England and (B) catchment of the River Severn, and (C) position of the geotechnical boreholes in relation to the superficial geology and two cross sections from BH01/85 to BH10/85 and WOB1 to WOB7.

2. METHODOLOGY

2.1 Desk top

2.1.1 Data for the geoarchaeological DBA have been derived from the following sources:

2.1.1.1 The BGS 1:50,000 and 1:10,000 maps (BGS 1988; 2022a, 2022b);

2.1.1.2. Geotechnical work carried out by CEMEX UK Operations Ltd in 1985 when 14 boreholes were drilled by cable percussion (BH01/85 – BH14/85) and in 2019 when 6 boreholes were drilled by a Dando rig (cable percussion) (WOB1 – WOB5 and WOB7) (see Appendix 2). Six boreholes lie very close to but not on the site, however they are included in the work.

2.1.1.3 Published and unpublished geological and archaeological literature[6].

2.1.2 The lithological unit descriptions from the original geotechnical drilling logs have been interpreted to produce an informal classification. This reflects the often diverse, sometimes sparce and subjective geological terminology used by the lead drillers on two widely separate occasions while aiming not to lose any pertinent information (Appendix 2). Descriptions used here are based on the major lithology: clay, sand or gravel. They can be adjusted with the addition of an adjectival prefix; for example: 'sandy clay', the major lithology of which is clay with a lesser fraction of sand. Two lithological descriptions which are retained from the original logs are 'stoney clay' and 'marl'; the former used in 1985 possibly represents solifluction deposits overlying any sand and gravel and seen by the author (see Watson 2019) at Ryal North Quarry *c*. 4km north of the present site; and the latter, 'marl', used in both drilling operations to describe the weathered mudstone bedrock. Each lithological unit is then assigned to a formal stratigraphic unit for the purposes of mapping and plotting of composite cross sections, for example, marl and mudstone are deposits pertaining to the Mercia Mudstone Group.

2.2 RockWorks

2.2.1 A RockWorks database was created with the lithological and positional data from the 20 geotechnical boreholes listed in Section 2.1. above (Figure 1C).

2.2.2 The RockWorks software was used to plot two composite cross sections through the site (Figure 2 and Figure 3) and two deposit models (Figure 4 and Figure 5). The latter accord with Historic England (2020) guidelines and were generated using an inverse distance interpolation algorithm to model the stratigraphy of the uninvestigated area on the basis of the nearest eight neighbours (i.e. borehole positions) and with a 114.46m cut off[7].

[6] The Portable Antiquities Scheme; Pastscape/Historic England Research Records; Royal Holloway, University of London, University of Leicester, University of Birmingham (2011) National Ice Age Network [data-set]. York: Archaeology Data Service [distributor] https://archaeologydataservice.ac.uk/archives/view/nian_eh_2010/ ; and Lorraine Mepham (2009) TERPS - The English Rivers Project [data-set]. York: Archaeology Data Service [distributor] https://doi.org/10.5284/1000063 were searched.

[7] This means that locations greater than 114.46m from any stratigraphic record are not modelled. The distance represents 15% of the maximum (i.e. north–south) dimension of the site.

2.3 Archive

2.3.1 The digital archive comprises a RockWorks 21 database housing the positional and stratigraphic data. These data will be held in perpetuity at the University of Winchester while exported versions of the data are included in this report as Appendices 1 and 2.

3. LITHOSTRATIGRAPHY

3.0.1 Deposits revealed in the boreholes from the site are shown as two composite cross sections (Figure 2 and Figure 3). Lithostratigraphic descriptions are provided in Appendix 2, while two deposit models map the upper contacts of the Mercia Mudstone Group with the superficial deposits (Figure 4) and the stratigraphic thickness of the fluvial sand and gravel deposits (Figure 5). The following table outlines the stratigraphy of the deposits from youngest to oldest:

1. Topsoil (Modern)

2. Brown clay and grey clay: possibly Holocene Alluvium

3. Slope deposits (Holocene colluvium and/or Pleistocene solifluction [Head])

4. Worcester Member (Pleistocene sand and gravel river terrace)

5. Holt Heath sand and Gravel Member (Pleistocene sand and gravel river terrace)

6. Mercia Mudstone Group (Triassic bedrock)

3.0.2 The depositional sequence is described in the text below in reverse stratigraphic order.

3.1 Mercia Mudstone Group

3.1.1 The bedrock lies between +3.87m OD (5.8m bgl) in BH14/85 in the northwest and +14.82m OD (3.10m bgl) in WOB2 in the north of the site. This is consistent with the topography of the east bank of the Severn valley which is more deeply scoured towards the west. The bedrock is found in all the boreholes.

3.1.2 The bedrock is reported as a hard red marl in the 1985 logs. In the 2019 drilling report the unit is divided in two: a top subunit between 0.1m and at least 2m thick and described as a ‘weathered marl’ or ‘weathered marl clay’; and an underlying unit described as ‘mudstone. The latter is present in all boreholes except WOB7. Green reduction spots are noted in WOB5. The total thickness of the Mercia Mudstone Group was not proven.

3.2 Holt Heath Sand and Gravel Member

3.2.1 Five boreholes (WOB2, BH05/85, WOB3, BH09/85 and WOB4) are believed to sample the earlier (than the Worcester Member) and altitudinally higher Holt Heath Sand and Gravel Member deposits and which lie along the eastern site boundary striking NNE / SSW. These boreholes not only coincide with the mapped area of the Member but, and significantly, they demonstrate the presence of a bedrock bench at +14±1m OD upon which the Holt Heath Sand and Gravel Member deposits accumulated. Deposits of the Worcester Member lie to the west on more deeply scoured basement. The borehole logs do not distinguish between the two terraces either on the basis of lithology or location.

3.2.2 The river sands and gravels lie between +14.30m OD (0.5m bgl) in BH09/85 and +17.18m OD in WOB4 where they outcrop; both boreholes are located towards the south on the main site (Figure 1C). The average thickness of the deposits pertaining to the Holt Heath Sand and Gravel Member is 2.4m (5 records) with a maximum of 3.2m in WOB3) (Figure 5). The lithology ranges from gravel, sandy gravel, gravelly sand to sand. Gravel is absent in two boreholes (WOB2 and BH09/85) and only sand is recorded.

3.3 Worcester Member

3.3.2 Fluvial sands and gravels of the Worcester Member lie unconformably over the bedrock between +7.65m OD (3m bgl) in WOB5 in the south and +11.30m OD (1.00m bgl) in BH08/85 in the centre east of the main site (Figure 1C and Figure 2). Lithologies of sandy gravel, clayey gravel, gravelly sand, sand and clayey sand are present in 12 boreholes. In general, and as far as can be ascertained from the logs, particle size fines upwards; that is to say sands overly gravels, there is one exception in BH14/85. The average thickness of the deposits pertaining to the Worcester Member is 2.54m (12 records) with a maximum of 4.5m in BH08/85.

3.3.3 For both the sand and gravel Members particle size classes for the sand grade are described as fine to medium and medium to coarse. Occasionally a silt grade is included. Gravels are described as fine to medium which suggests 4 – 16mm[8]. Rounding of gravels is rarely noted and where it is, the particles are angular.

3.3.4 No organic deposits are recorded in the boreholes.

3.4 Slope deposits

3.4.1 Lithology classes that have been grouped as Slope deposits are stoney clay, sandy clay and brown clay. They are found in 13 boreholes with a maximum thickness of 3m in WOB5 *c*.120m south of the main site. In every case the slope deposits lie above strata assigned to the sand and gravel Members or to the bedrock (WOB1 is the only example of slope deposits lying directly on the bedrock) (Figure 1C, Figure 2 and Figure 3). The lithology is predominantly clay, coloured brown or red/brown, and is derived from higher exposures of the bedrock via weathering and mass movement.

3.4.2 The terraced east side of the valley of the River Severn is highly conducive to mass movement; Towbury Hill has an altitude of *c* +30m OS and lies only 290m to the east of the site. The land steps down to the Holt Heath Sand and Gravel Member at *c.*+17m OD, then to the Worcester member at *c*.+11m OD and finally to the modern floodplain all within the space of *c*.680m. The slope deposits represent either colluvium laid down in the Holocene or possibly earlier Head that accumulated via solifluction in a periglacial environment during the Late Pleistocene; deposits labelled as *stoney clay* may pertain to the latter unit (see Section 2.2 above). The mobilisation of the varied Pleistocene terrace sediment lithologies will result in a heterogeneous and localised interdigitating deposits of which sandy and stoney clays are examples. Their morphology would tend to blanket the underlying sands and gravels being thicker at the foot of the terraces and thin or negligible in the centres. These deposits or at least the uppermost fraction, are likely to be oxidised and bioturbated to the detriment of the preservation of organic remains.

[8] As measured on the Wentworth scale or 2 – 20mm according to the ISO 14688-1:2002. It is surprising that coarser particles are not recorded.

3.5 Alluvium

3.5.1 Two boreholes (BH01/85 and BH02/85) located in the northwest of the site have neither sand nor gravel components but instead record thick deposits of stiff red to grey clay in the former and soft to hard red clay in the latter above the bedrock. Both boreholes lie on the mapped Holocene alluvium where it laps onto the Worcester Member. Grey and brown sediment colours in the vadose zone are associated with reduced and oxidised environments of deposition that can change with a fluctuating water table. Unfortunately, there is insufficient information to determine if these deposits represent alluvium for which a grey colouration would be evidence, or if they are *in situ* weathered mudstone where hard and red clays would be expected. Inter digitating slope deposits coloured red from a bedrock source could also mask fine grained grey alluvium.

3.5.2 Grey clays are also recorded outcropping in WOB2 (1.1m thick) in the north and WOB7(0.5m thick) in the south. The latter borehole is located on the mapped alluvium and the deposit is undoubtably a high level flood plain sediment (+10.30m OD). The former borehole on the other hand lies well above the flood plain at +17.92m OD and the grey clay may represent a pond or Made ground.

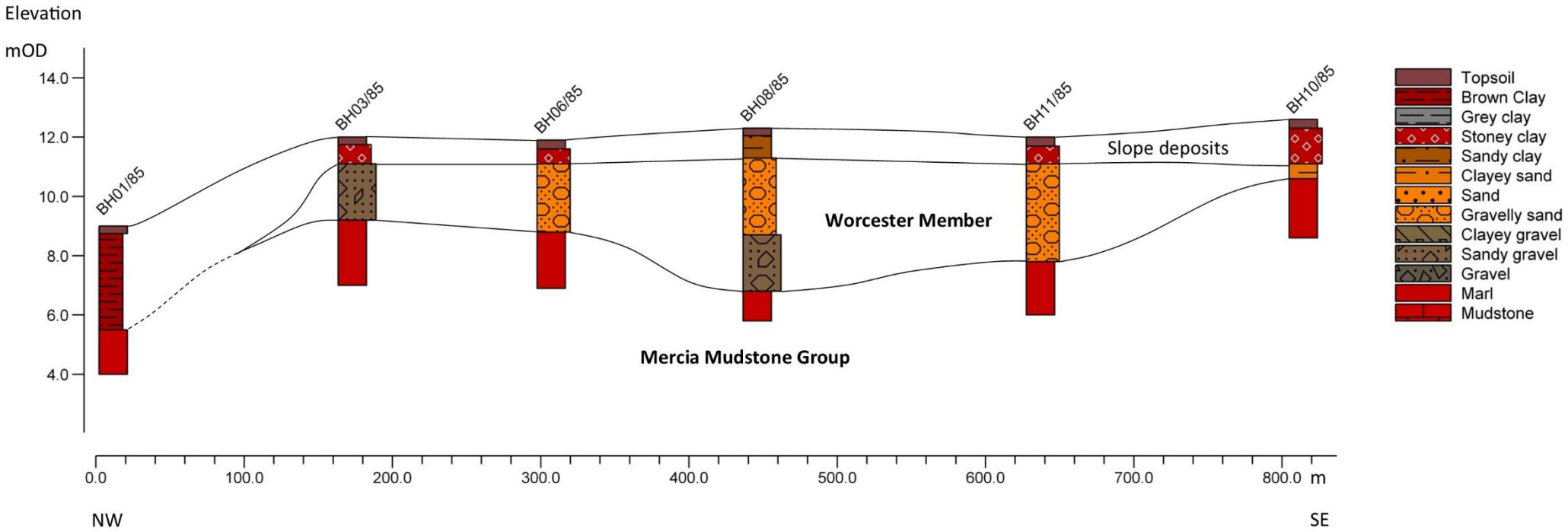

Figure 2. NW to SE lithostratigraphic cross section of the Worcester Member. Vertical exaggeration x20.

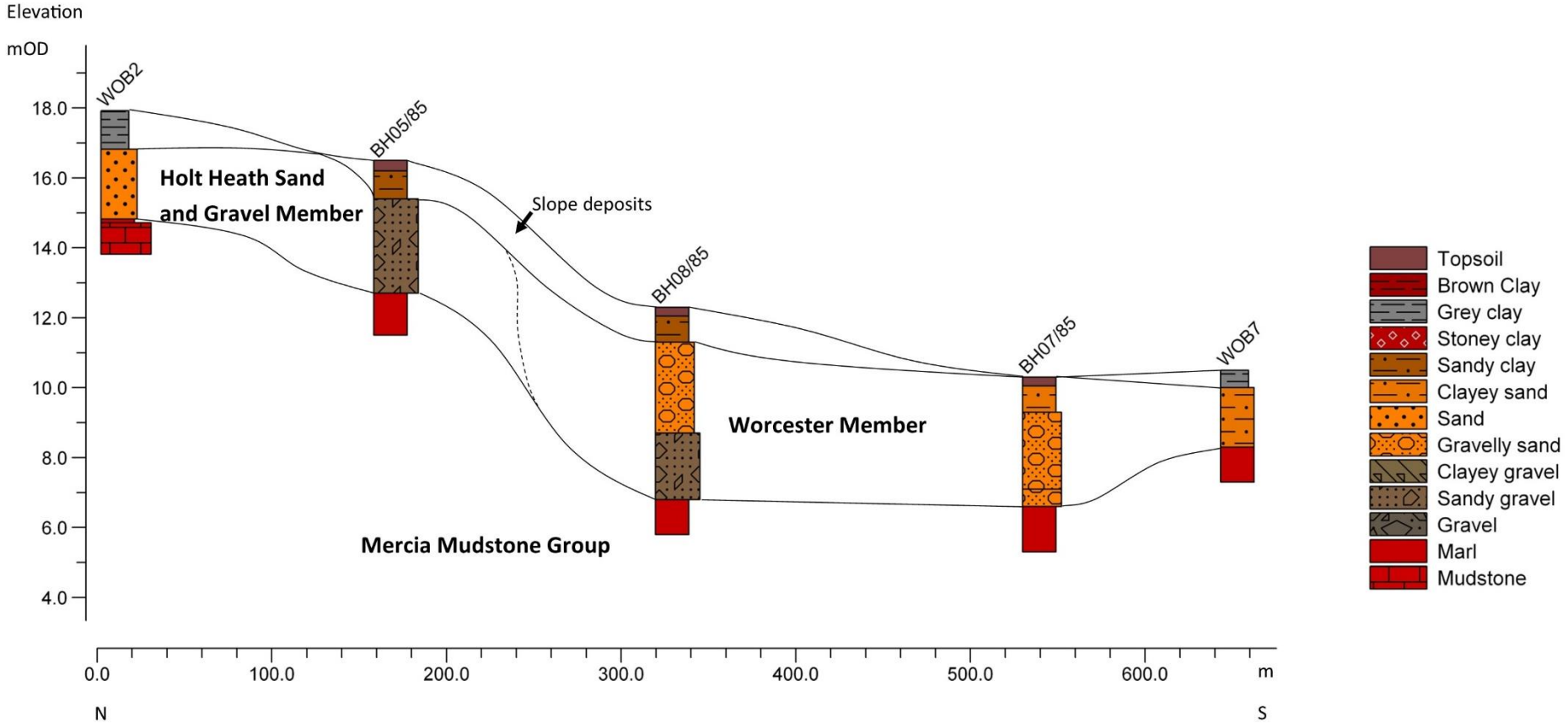

Figure 3. N to S lithostratigraphic cross section showing the Holt Heath Sand and Gravel Member on the NE border of the Ripple East site and the Worcester Member which occupies the major area of the site. Vertical exaggeration x20.

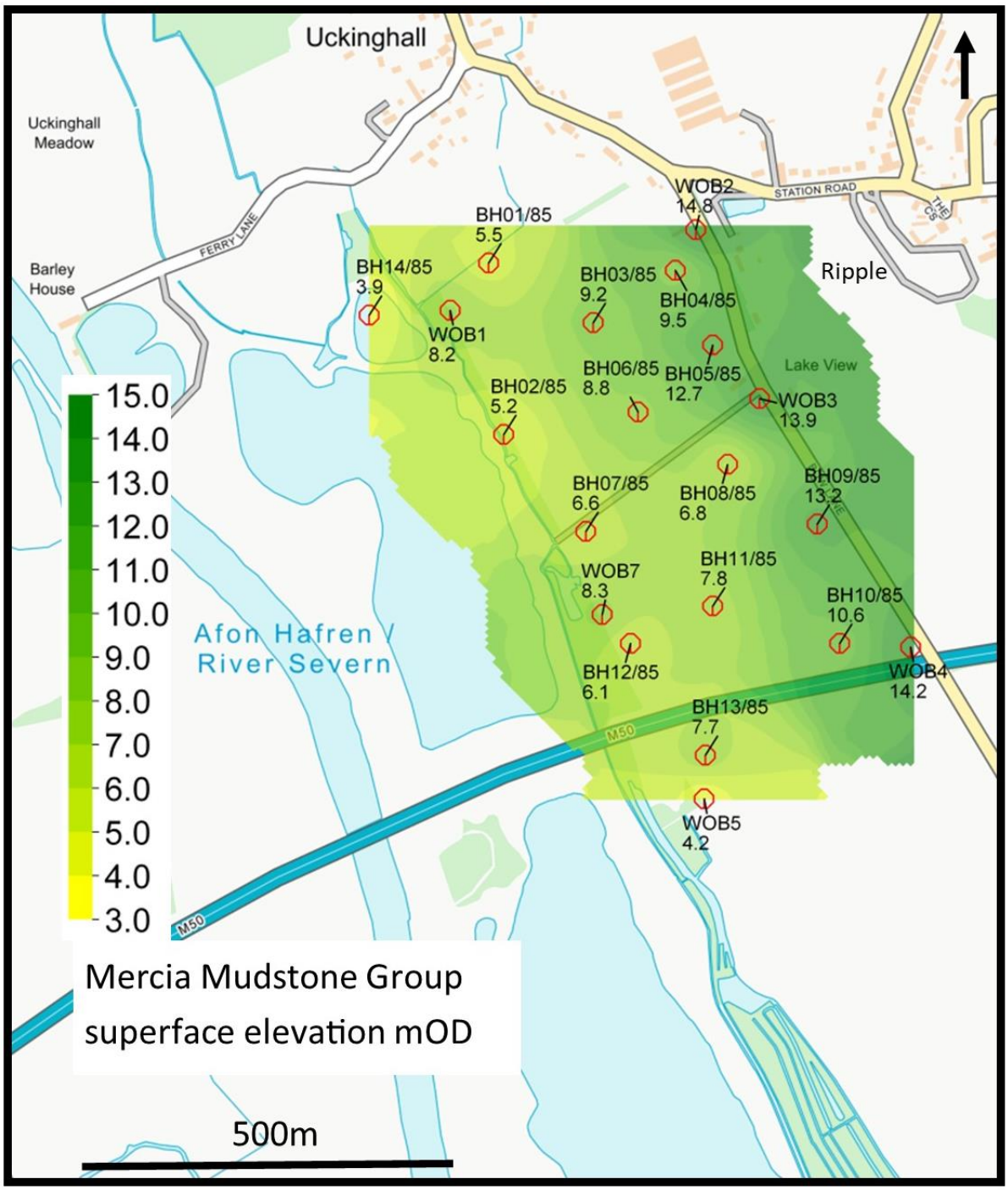

Figure 4. Modelled map of the superface (upper contact) of the Mercia Mudstone Group bedrock at Ripple East.

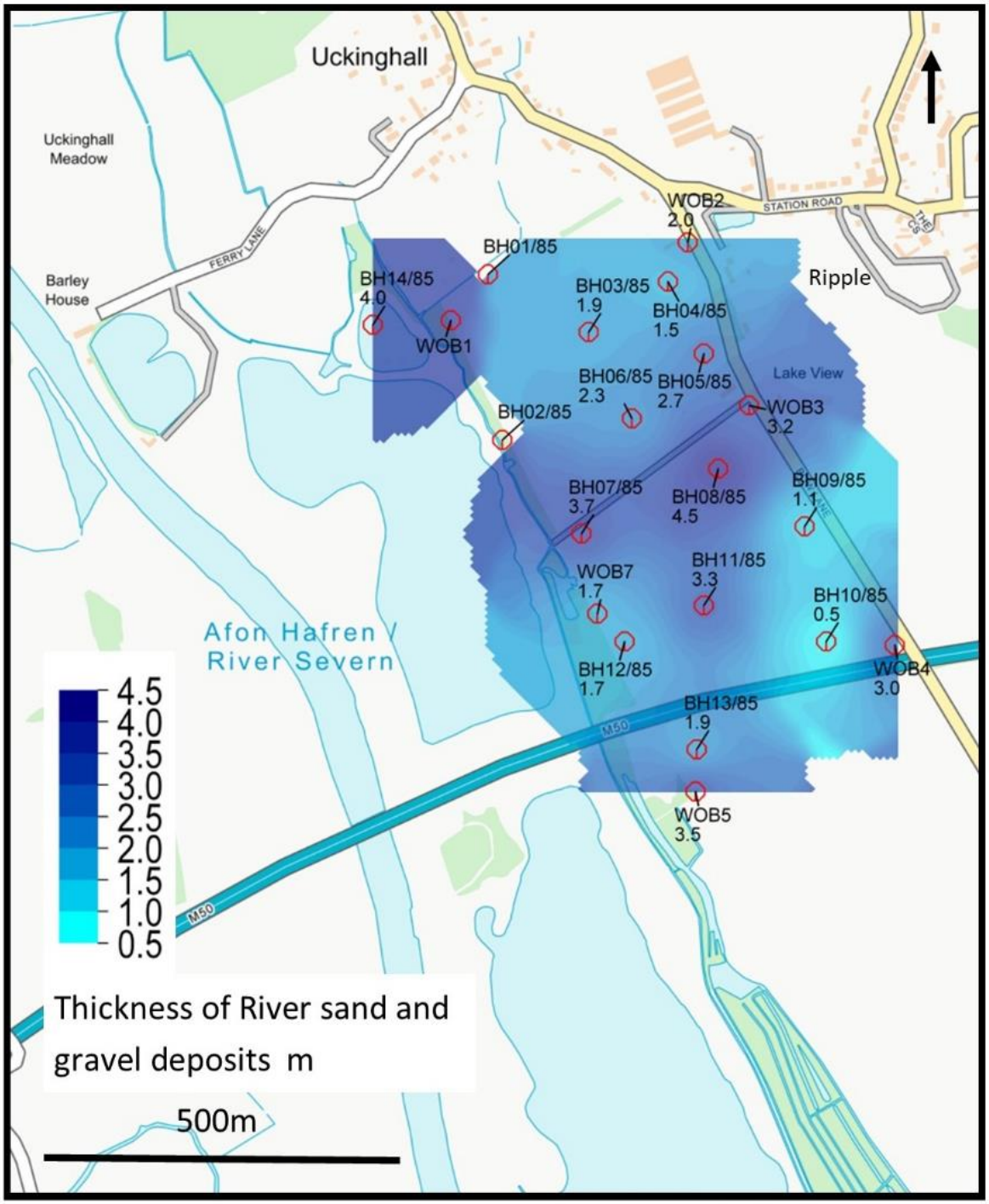

Figure 5. Modelled map of the thickness of the River sand and gravel deposits at Ripple East.

4. ASSESSMENT OF THE GEOARCHAEOLOGICAL POTENTIAL OF RIPPLE EAST

4.1 The Worcester Member has an unknown potential for palaeoenvironmental, artefactual, human and faunal remains according to Russell and Daffern (2014), however and as the authors note, on the River Avon and the Carrant Brook at Beckford (11km east) deposits dating from MIS4 to MIS2 (71ka – 14ka) (Riggs *et al* 1975) or MIS3 to MIS2 (Keith Wilkinson pers.com. 2022) are correlated with both the Worcester Member and the Holt Heath Sand and Gravel Member and not only contain artefacts and mammalian remains but also pond filling organic remains from the intercalated Fladbury Beds. There is therefore *a priori* evidence to suppose the existence of similar remains at the Ripple East site, even though Beckford is in the Avon catchment. In the following discussion of the geoarchaeological potential the Worcester Member will be the main focus. First the mode of preservation of *in situ* biological and artefactual remains will be overviewed and; secondly, any criteria thus revealed that appear to control preservation will be applied to the Member to assess its potential according to the Aims of the work (Section 1.8).

4.2 The preservation of biological remains depends first on the nature of the remains themselves: bone will preserve best within dry alkaline sediments whereas plant remains in form of peat will only be found within minerogenic sedimentary units that lie below the water table and have remained waterlogged from the time of burial to the time of exposure. Secondly, preservation is also a factor of the mode of deposition: bone, which is a relatively tough material, is more likely to resist destruction during fluvial transport than plant remains and invertebrates, and tends to accumulate within deposits of similar particle size. Peat, on the other hand, offers little physical resistance to weathering and will tend to be found *in situ* in backswamp environments (for example, abandoned channels) on the floodplain. Its preservation depends upon being buried during low energy processes (i.e. the deposition of suspended clay and silt particles in flood waters).

4.3 The preservation of archaeological artefacts and in this case Late Upper Palaeolithic lithics manufactured from flint or chert, is also determined by their size. Like bone, fluvial transport will weather the artefacts and tend to sort or rework them by their size and shape. Artefacts *in situ* however are found in association with the substrate upon which humans deposited them. Since the most common substrate in the British Isles over which human groups operated are top soils of clay- and silt-size, then the preservation of *in situ* artefacts will depend on the preservation of these fragile or low energy environments. The question therefore is whether the Worcester Member on the site fulfils the criteria for the preservation of clay and silt grade deposits within which *in situ* artefacts and organic plant remains may be found, namely low energy environments of deposition and a high persistent water table.

4.4 The Worcester Member is a clastic, minerogenic, fluvial deposit. The vast bulk of the Member is associated with incision and cold period sedimentation at the end of the Dimlington Stadial. The calibre of its constituent particles range from gravel to fine sand and these deposits can be up to 4.5m thick (BH08/85). The lithology is described in terms of two particle size descriptors, for example, sandy gravel or clayey sand, which implies a certain textural immaturity (Section 3.3.2). This is to be expected on the braid plain where changing flow regimes in both power and channel route will mix deposits and finer particles fill the interstices of point-contact gravels (Miall 1995). In general, however, deposits fine upwards as channels are filled and water depth and flow energy decrease. Lenses of finer grade deposit buried within coarser deposit are not in evidence. Clay and silt grades tend to be associated with sands in the uppermost 1m – 2m of the Member. It is at this point in the stratigraphy that fine grained sedimentation and the possibility of preservation of *in situ* biological remains and artefacts occurs.

This is primarily a consequence of a warming climate and a falling energy environment of the evolving Windermere interstadial. [9] Towards the top of the stratigraphy, however, on even the slightest of slopes some reworking of the strata by mass movement will most probably have taken place.

4.5 The relatively narrow valley of the Severn River (*c*.600m) and the low altitude of the Worcester Member terrace situates the water table within the sand and gravel aquifer at *c*.+15m OD at WOB2 in the northeast, falling to *c*.+9.5m in WOB1 and WOB7 in the northwest and south respectively. This implies that peat remains could exist in fine grained sediment below this datum even though none is recorded in the boreholes (CEMEX UK Operations Ltd n.d.).[10] Even so, clayey sand sampled in WOB7 and BH07/85 is a possible candidate for the recovery of peat or *in situ* artefacts (Figure 3). The uppermost strata of the Worcester Member is therefore conducive to peat preservation. Rare peat lenses interbedded with sands have been found on the Bow Farm Quarry site and most probably dating to the Lateglacial (13 – 10ka) (Howard 2019, 7). The location of this peat is believed to be on the terrace of the Worcester Member, however, data for the exact location of the Bow Farm Quarry boreholes was unavailable.

4.6 In conclusion, the uppermost 1m – 2m of the Worcester Member has the potential to preserve *in situ* palaeoenvironmental and artefactual remains: appropriate fine grained sedimentary conditions are known to exist and are located within a waterlogged environment. Reworked lithics and bone, on the other hand, could be found within coarser facies although their potential presence must be considered low.

4.7 The Holt Heath Sand and Gravel Member can be similarly assessed. The representation of the Member on the site is very minor and the lithology does not include a notable clay and silt grade fraction that is readily distinguishable from slope deposits. Furthermore, the bedrock bench on which the deposits rest has an elevation of 14±1m OD and is approximately level with the water table. This will therefore augur against the existence of persistent waterlogged conditions within the Member. On the other hand, should a palaeochannel exist then a thicker body of deposit would improve the possibility for the preservation of fine grained organic or minerogenic strata; none however are evident. If the Member on the site is of MIS3 date, then it is of potential significance as the period saw the last Neanderthals and first modern humans in Britain. The gravels should be OSL dated to better assess their Palaeolithic archaeological potential.

5. CONCLUSIONS

5.1 Examination of the 20 geotechnical boreholes from the Ripple East site has revealed the presence of two fluvial terraces: the higher and earlier terrace is correlated by the BGS with the Holt Heath Sand and Gravel Member and rests on a Mercia Mudstone Group bedrock bench at +14±1m OD; the later terrace is correlated with the Worcester Member and lies between +7.65m OD in the south and +11.30m OD in the centre east of the main site also on the mudstone bedrock (Figure 1C and Figure 2).The average thickness of the former is 2.4m (5 records) and of the latter 2.54m (12 records).

[9] It should be noted that although the climate is warming periglacial conditions will persist and near arctic weather will not militate against fine grained sedimentation both organic and minerogenic. Furthermore, the Worcester Member does not have an absolute chronology so its association with the Windermere interstadial is at present an assumption.

[10] Cable percussive drilling of gravels is crude and thin fine-grained strata can be overlooked or destroyed in the process.

5.2 A full assessment of the potential for Palaeolithic archaeology associated with either terrace is at present difficult because various lacunae exist. The first is that there is no direct absolute age range for the deposits. Secondly, although boreholes WOB7 and BH07/85 on the Worcester Member record clayey sand and the upper 1-2m is tentatively postulated as conducive to the recovery of peat or *in situ* artefacts, this observation is based on work designed to recover gravels for economic purposes and not geoarchaeological logging of purposeful geoarchaeological boreholes. Finally, no macro biological nor archaeological remains are known form the two Members in the immediate area. The record of peat further south at the Bow Farm Quarry site although encouraging is unfortunately insecurely located.

5.3 The first two points noted above can be addressed by purposive geoarchaeological boreholes using a rig capable of collecting enclosed cores (i.e. a dynamic sampler) which could then be described in detail and sampled for Optically Stimulated Luminescence dating and biostratigraphic examination. This methodology has proven successful in work on fluvial terraces at the Pan Lane site, Newport on the Isle of Wight (Wilkinson *et al* 2018). The final point – recovery of macro biological and lithic remains – is best approached by a watching brief on exposed quarry faces.

5.4 Holocene archaeology and environmental remains are not subject to this report. Extensive reviews can be found in Cotswold Archaeology (2022) and Howard (2019).

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5.2 Nick Watson wrote the report and produced the illustrations. Keith Wilkinson commented on and copy edited the final version of the report.

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APPENDIX 1: BOREHOLE LOCATIONS

Bore	Easting	Northing	Elevation m OD	Total Depth m
BH01/85	386870	237670	9	5
BH02/85	386890	237440	9.2	5
BH03/85	387010	237590	12	5.00
BH04/85	387120	237660	12.1	5.00
BH05/85	387170	237560	16.5	5.00
BH06/85	387070	237470	11.9	5.00
BH07/85	387000	237310	10.3	5.00
BH08/85	387190	237400	12.3	6.50
BH09/85	387310	237320	14.8	5.00
BH10/85	387340	237160	12.6	4.00
BH11/85	387170	237210	12	6.00
BH12/85	387060	237160	8.7	5.00
BH13/85	387160	237010	10.73	5.00
BH14/85	386710	237600	9.67	8.00
WOB1	386818.48	237606.29	10.15	5.00
WOB2	387147.45	237714.57	17.92	4.10
WOB3	387232.79	237488.02	17.13	4.60
WOB4	387435.14	237155.01	17.18	3.80
WOB5	387158.46	236951.44	10.65	9.00
WOB7	387022	237198.66	10.5	3.20

Ordnance Datum elevation of borehole collar.

APPENDIX 2: BOREHOLE LITHOSTRATIGRAPHY

Data derived and amended from CEMEX UK Operations Ltd: Ripple East, Bow Lane, Ripple, Worcestershire Volume 2.0 Environmental Statement: Hydrology, Hydrogeology, Flood Risk, Geology Appendix 5.2 Borehole Logs. (unknown date).

Bore	Top	Base	Lithology	Comments
BH01/85	0.00	0.25	Topsoil	
BH01/85	0.25	3.50	Brown Clay	Stiff red to grey CLAY
BH01/85	3.50	5.00	Marl	Red MARL
BH02/85	0.00	0.20	Topsoil	
BH02/85	0.20	4.00	Brown Clay	Soft to hard red CLAY
BH02/85	4.00	5.00	Marl	Hard red MARL
BH03/85	0.00	0.25	Topsoil	
BH03/85	0.25	0.90	Stoney clay	Brown stoney CLAY
BH03/85	0.90	2.80	Sandy gravel	Brown (medium grained) SAND and (small to medium sized) GRAVEL
BH03/85	2.80	5.00	Marl	Hard red MARL
BH04/85	0.00	0.25	Topsoil	
BH04/85	0.25	1.10	Stoney clay	Stoney CLAY
BH04/85	1.10	2.60	Sandy gravel	Brown sandy GRAVEL
BH04/85	2.60	5.00	Marl	Hard red MARL
BH05/85	0.00	0.30	Topsoil	
BH05/85	0.30	1.10	Sandy clay	Brown sandy CLAY
BH05/85	1.10	3.80	Sandy gravel	Brown (fine grained) very sandy (small/medium) GRAVEL to(small/medium) very gravelly (fine to medium) SAND
BH05/85	3.80	5.00	Marl	Hard red MARL
BH06/85	0.00	0.30	Topsoil	
BH06/85	0.30	0.80	Stoney clay	Stoney CLAY
BH06/85	0.80	3.10	Gravelly sand	Brown (medium) very gravelly (medium/fine grained) SAND (Lignite present.)
BH06/85	3.10	5.00	Marl	Hard red MARL

BH07/85	0.00	0.25	Topsoil	
BH07/85	0.25	1.00	Clayey sand	Brown clayey SAND
BH07/85	1.00	3.20	Gravelly sand	Red/brown (medium sized) slightly gravelly (medium/fine grain sized) SAND
BH07/85	3.20	3.70	Gravelly sand	Red brown clayey (medium sized) gravelly (coarse/medium grained) SAND
BH07/85	3.70	5.00	Marl	Red brown MARL
BH08/85	0.00	0.25	Topsoil	
BH08/85	0.25	1.00	Sandy clay	Brown sandy CLAY
BH08/85	1.00	3.60	Gravelly sand	Brown slightly clayey very silty (small to medium sized) gravelly (fine grained) SAND
BH08/85	3.60	5.50	Sandy gravel	Brown slightly silty (fine/medium grained) sandy (small to medium sized) GRAVEL
BH08/85	5.50	6.50	Marl	Hard red MARL
BH09/85	0.00	0.30	Topsoil	
BH09/85	0.30	0.50	Stoney clay	Brown stoney CLAY
BH09/85	0.50	1.60	Sand	Brown slightly clayey silty (medium) slightly gravelly (medium/fine grained) SAND
BH09/85	1.60	4.50	Marl	Hard red CLAY (MARL)
BH09/85	4.50	5.00	Marl	Red MARL
BH10/85	0.00	0.30	Topsoil	
BH10/85	0.30	1.50	Stoney clay	Brown stoney CLAY
BH10/85	1.50	2.00	Clayey sand	Brown clayey SAND
BH10/85	2.00	4.00	Marl	Hard red MARL
BH11/85	0.00	0.30	Topsoil	
BH11/85	0.30	0.90	Stoney clay	Stoney CLAY
BH11/85	0.90	4.20	Gravelly sand	Brown (small/medium) gravelly (coarse/medium grained) SAND to red (medium grained) SAND.
BH11/85	4.20	6.00	Marl	Hard red MARL
BH12/85	0.00	0.30	Topsoil	
BH12/85	0.30	0.90	Stoney clay	Brown stoney CLAY
BH12/85	0.90	1.20	Sand	Brown SAND

BH12/85	1.20	2.60	Sandy gravel	Brown (medium grained) very sandy (small/medium) GRAVEL
BH12/85	2.60	5.00	Marl	Hard red MARL
BH13/85	0.00	0.30	Topsoil	
BH13/85	0.30	1.10	Sandy clay	Brown sandy CLAY
BH13/85	1.10	3.00	Sandy gravel	Orange brown clayey silty (medium/coarse grained) sandy (medium) angular GRAVEL
BH13/85	3.00	5.00	Marl	Hard red MARL
BH14/85	0.00	0.40	Topsoil	
BH14/85	0.40	1.80	Brown Clay	Soft red/brown silty CLAY
BH14/85	1.80	3.40	Clayey gravel	Grey/brown slightly (small in size) gravelly fine grained sandy CLAY to brown (fine grained) sandy clayey (small/medium sized) GRAVEL (Barely workable)
BH14/85	3.40	5.80	Gravelly sand	Brown (small/medium sized) gravelly (medium/fine grained) SAND
BH14/85	5.80	8.00	Marl	Hard red and green MARL
WOB1	0.00	0.95	Brown Clay	Stiff, dark brown CLAY.
WOB1	0.95	2.00	Sandy clay	Grey, brown, sandy MARL
WOB1	2.00	4.00	Marl	Weathered MARL.
WOB1	4.00	5.00	Mudstone	MUDSTONE (Mercia Mudstone).
WOB2	0.00	1.10	Grey clay	Stiff, grey CLAY
WOB2	1.10	3.10	Sand	Fine, grey, silty SAND
WOB2	3.10	3.20	Marl	Weathered, marl CLAY
WOB2	3.20	4.10	Mudstone	MUDSTONE (Mercia Mudstone).
WOB3	0.00	1.10	Gravelly sand	Dry, dense, fine, dark brown, silty, slightly gravelly SAND.
WOB3	1.10	3.20	Gravel	Dense, dry, slightly silty, GRAVEL.
WOB3	3.20	4.10	Marl	Weathered, marl CLAY
WOB3	4.10	4.60	Mudstone	MUDSTONE (Mercia Mudstone).
WOB4	0.00	1.20	Gravelly sand	Dry, dense, fine, dark brown, silty, slightly gravelly SAND.
WOB4	1.20	3.00	Gravel	Dense, dry, silty GRAVEL.
WOB4	3.00	3.10	Marl	Weathered marl CLAY.

WOB4	3.10	3.80	Mudstone	Mudstone (Mercia Mudstone).
WOB5	0.00	3.00	Brown Clay	Stiff, red brown CLAY.
WOB5	3.00	6.50	Gravelly sand	Soft, red brown, silty, slightly gravelly SAND.
WOB5	6.50	7.35	Mudstone	Hard, red brown, slightly green MUDSTONE.
WOB5	7.35	9.00	Marl	Soft, weathered MARL.
WOB7	0.00	0.50	Grey clay	Grey, stiff CLAY
WOB7	0.50	2.20	Clayey sand	Fine, grey, clayey, SAND
WOB7	2.20	3.20	Marl	Weathered red, firm to soft MARL.